

Land Cover Change and Hydrologic Response

- Introduction:** In this exercise you will investigate the manner in which changes in land cover over the past 25 years have affected runoff processes in SE Arizona.
- Goal:** To familiarize yourself with AGWA and the various uses and limitations of hydrologic modeling for landscape assessment.
- Assignment:** Run the SWAT model on a large watershed in the San Pedro River Basin and the KINEROS model on a small subbasin using 1973 and 1992 NALC land cover.
- Keywords:** Watershed assessment, Hydrologic model, Rainfall interpolation, Continuous vs. event-based modeling
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A Short Introduction to Hydrologic Modeling for Watershed Assessment

The basic tenet of watershed management is that direct and powerful linkages exist among spatially distributed watershed properties and watershed processes. Stream water quality changes, especially due to erosion and sediment discharge, have been directly linked to land uses within a watershed. For example, erosion susceptibility increases when agriculture is practiced on relatively steep slopes, while severe alterations in vegetation cover can produce up to 90% more runoff than in watersheds unaltered by human practices.

The three primary watershed properties governing hydrologic variability in the form of rainfall-runoff response and erosion are soils, land cover, and topography. While topographic characteristics can be modified on a small scale (such as with the implementation of contour tillage, terracing, and in agricultural fields), variation in watershed-scale hydrologic response through time is primarily due to changes in the type and distribution of land cover.

Watershed modeling techniques are useful tools for investigating interactions among the various watershed components and hydrologic response (defined here as rainfall-runoff and erosion relationships). Physically-based models, such as the KINEmatic Runoff and EROSION model (KINEROS) are designed to simulate the physical processes governing runoff and erosion (and subsequent sediment yield) on a watershed. Lumped parameter models such as SWAT are useful strategic models for investigating long-term watershed response. These models can be useful for understanding and interpreting the various interactions among spatial characteristics insofar as the models are adequately representing those processes. Because of the difficulties associated with providing parameter input data to physically-based models, studies of the models' inherent response to such critical factors as watershed representation and the impacts of error have generally been limited in scope and/or to synthetic data. It is the intention of this research to utilize observed data and undertake a comprehensive investigation of such inter-relationships in order to improve the manner in which KINEROS may be used in watershed investigations.

The percentage and location of natural land cover influences the amount of energy that is available to move water and materials. Forested watersheds dissipate energy associated with rainfall, whereas watershed with bare ground and anthropogenic cover are less able

to do so. The percentage of the watershed surface that is impermeable, due to urban and road surfaces, influences the volume of water that runs off and increases the amount of sediment that can be moved. Watersheds with highly erodible soils tend to have greater potential for soil loss and sediment delivery to streams than watersheds with non-erodible soils. Moreover, intense precipitation events may exceed the energy threshold and move large amounts of sediments across a degraded watershed (Junk et al., 1989; Sparks, 1995). It is during these events that human-induced landscape changes may manifest their greatest negative impact.

The Study Area

The San Pedro River flows north from Sonora, Mexico into southeastern Arizona (Figure 1). With a wide variety of topographic, hydrologic, cultural, and political characteristics, the basin represents a unique study area for addressing a range of scientific and management issues. The area is a transition zone between the Chihuahuan and Sonoran deserts and has a highly variable climate with significant biodiversity. The watershed is approximately 3150 km² and is dominated by desert shrub-steppe, riparian, grasslands, agriculture, oak and mesquite woodlands, and pine forests. The basin supports one of the highest numbers of mammal species in the world and the riparian corridor provides nesting and migration habitat for over 400 bird species. Large changes in the socio-economic framework of the basin have occurred over the past 25 years, with a shift from a rural ranching economy to considerably greater urbanization. As the human population has grown, so too has groundwater withdrawal, which threatens the riparian corridor and the long-term economic, hydrologic, and ecological stability of the basin.

Significant land cover change occurred within the San Pedro Basin between 1973 and 1997. Satellite data were acquired for the San Pedro basin for a series of dates covering the past 25 years: 1973, 1986, 1992, and 1997. Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) satellite images have been reclassified into 10 land cover types ranging from high altitude forested areas to lowland grasslands and agricultural communities with 60 meter resolution. The most significant changes were large increases in urbanized area, mesquite woodlands, and agricultural communities, and commensurate decreases in grasslands and desert scrub. This overall shift indicates an increasing reliance on groundwater (due to increased municipal water consumption and agriculture) and potential for localized large-scale runoff and erosion events (due to the decreased infiltration capacities and roughness associated with the land cover transition).

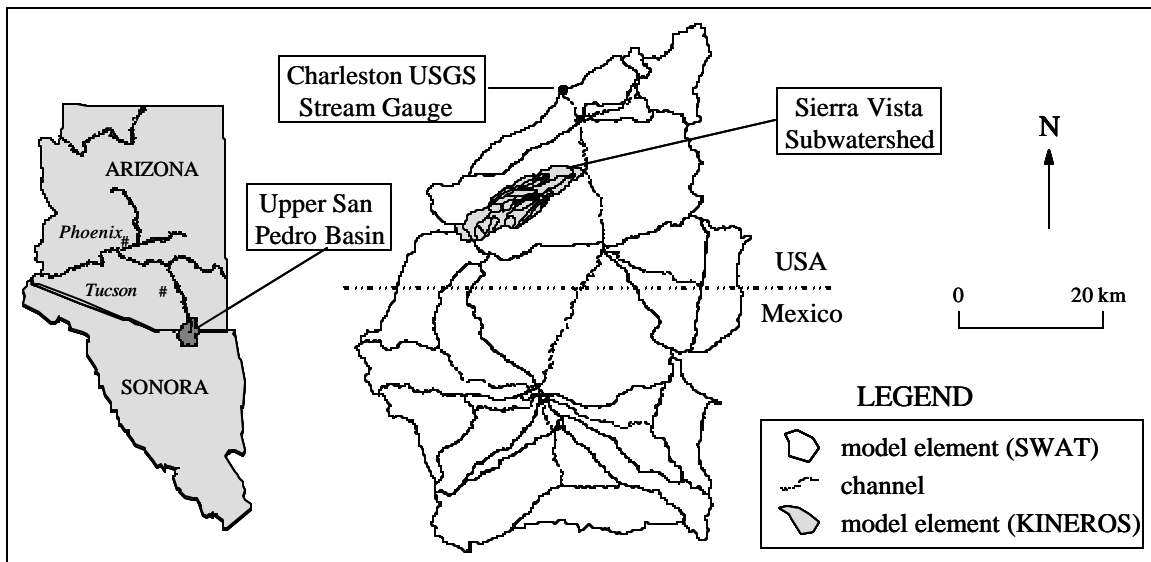
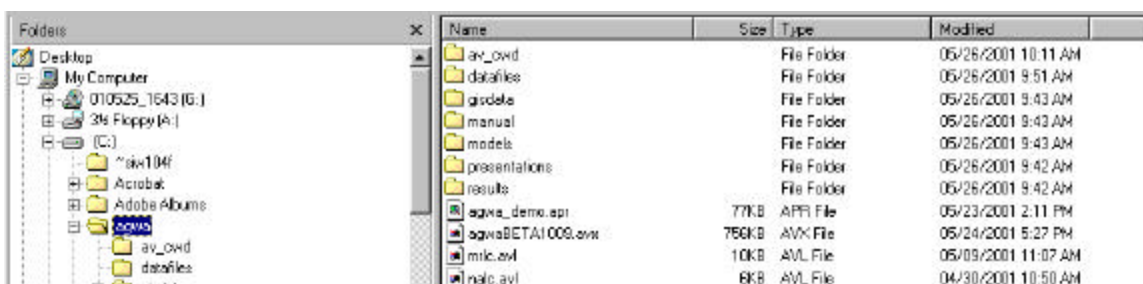


Figure 1. Locations of the Two Study Areas within the Upper San Pedro River Basin you will be modeling today. The larger basin (3160 km²) will be modeled using SWAT and drains to the Charleston USGS runoff gauging station. This basin encompasses the smaller watershed (92 km²), labeled here as “Sierra Vista subwatershed”, is to be modeled using KINEROS. Upland and channel elements are shown as they may be used in the SWAT simulations, and the upland and lateral elements (channels are withheld for clarity) used to parameterize KINEROS are outlined in the smaller watershed.

Installation

All of the data necessary to model runoff within the study area is provided on the accompanying CD. To install AGWA perform the following steps:

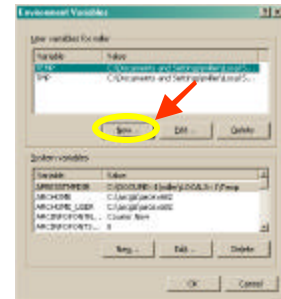
1. Copy the AGWA extension called “**agwa1_3.avx**” into the extensions folder on your hard drive. This folder is called “EXT32” and is usually installed in the following path: <X>: \ESRI\AV_GIS30\ARCVIEW\EXT32, where <X> is the drive onto which ArcView was installed.
2. Copy the necessary data onto your hard drive.
 - a. *Easy installation*: drag the entire contents of the CD onto your hard drive. This will necessitate approximately 50 Mb of disk space. You will end up with a directory structure like:



- b. *Alternative installation.* If you prefer to avoid adding all the data from the CD onto your hard drive, you may opt to re-create only part of the installation. At a minimum, AGWA will need access to files found under the “datafiles” and “models” directories.
3. You may choose to add an environmental variable to your system folder to ease the use of AGWA. As noted above, AGWA uses files found on the installation CD. By setting an environmental variable you can instruct AGWA where to find these files:

- a. *Windows 2000:*

- i. *Start... Settings... Control Panel... System*
 - ii. Click on the “Advanced” tab... then “Environmental Variables”
 - iii. Click the “New” button
 - iv. Variable Name: **agwa**
 - v. Variable Value: **c:\agwa**, or the master agwa directory created above



- b. *Windows NT:* Open the Windows Control Panel, double-click on the Systems icon. Select the Environment tab, and create the variable named AGWA with the variable value set to the path leading to the directory containing the “databases” and “models” folders. In the example above this would be “c:\agwa”. **Important:** do not use spaces in the path or ArcView will have trouble.

- c. *Windows 95/98:* On Windows 95/98 systems, you must add the following lines to the autoexec.bat file:

```
set AGWA=agwadir
```

where agwadir is the path leading to the directory containing the “databases” and “models” folders. In the example above this would be “c:\agwa”. **Important:** do not use spaces in the path or ArcView will have trouble. Use any text editor to open the autoexec.bat file, which can be found on the c:\ prompt on most Windows machines.

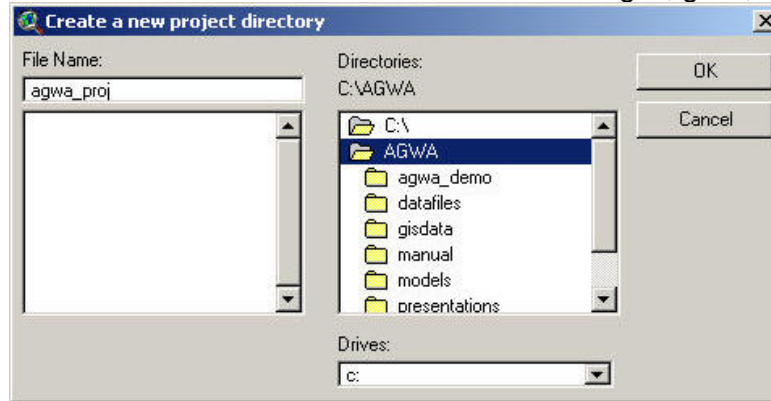
Getting Started

Start a new ArcView session. You do not need to add data to the view right away. Start by turning on the AGWA extension.

click on “file... extension”. Turn on AGWA by checking the box next to “AGWA v. 1.3”

The first time any project starts up AGWA it *must* be saved to a new project. AGWA will create a customized directory structure for each project file to simplify file management.

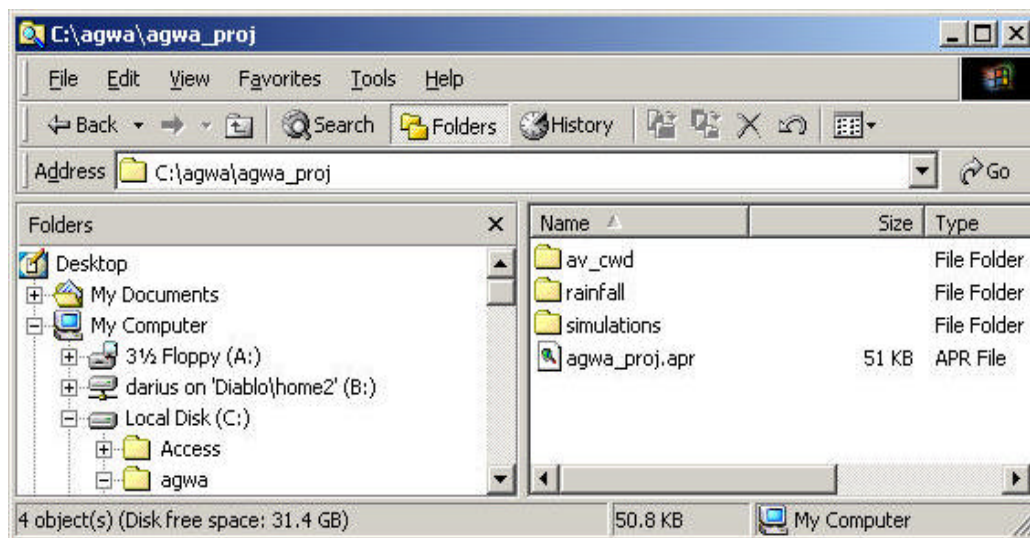
Setting Up the Project and the Working Directory - The working directory is the default location where ArcView will write coverages, grids, and tables generated during



the watershed assessment process. When the AGWA extension is first turned on, the user is prompted to save/create a new project as shown below. AGWA will use the name provided by the user and create a standard project file structure. Given the project name "agwa_proj"

under "c:\agwa" as shown here, a directory will be created called "c:\agwa\agwa_proj", and the project will be named "c:\agwa\agwa_proj\agwa_proj.apr". The working directory for the project will be pointed to a folder called "c:\example\project\av_cwd".

The resultant file structure is shown here:



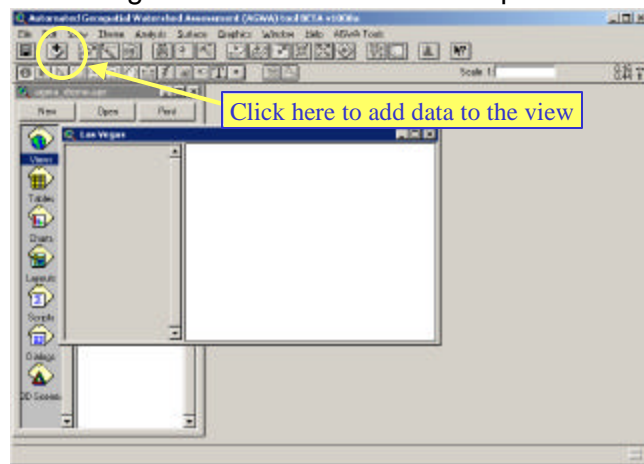
All files created by AGWA in the course of the project will be placed in the current working directory. **Please note:** even if a project has been previously saved as another name, AGWA will force the user to save the project with a new name with the above-described file structure.

A Note About Moving Spatial Data - It is important to remember that when using ArcView spatial data (coverages, themes, shapefiles, and grids) should not be moved from one directory into another using Microsoft Windows Explorer. This can create errors within the spatial data files, and should not be attempted unless the entire directory (up one level from the data sets themselves) in which the files reside is moved. Alternatively, if individual spatial data layers must be moved, then this should be done using ArcView. When a view is active, select 'Manage Data Sources' from the 'File' menu at the top of the screen. This will bring up a window that will enable you to transfer data layers from one directory to another without breaking the internal structure of spatial data files.

Let's start this exercise by loading data into ArcView. Create two new views. Change their names by clicking on "View... Properties"... name one "Las Vegas" and the other "San Pedro". Now we need to add data to the views.

Open up the "Las Vegas" View by double-clicking on its name. You will be presented with the following screen →

Add data to the view by clicking on the "+" button at the top. You will need to add the following grids from the agwa\gisdata\lasvegas directory:



Airport.shp - National Weather Service raingauge

Kineros1.shp - outlet of a watershed be modeled with KINEROS

Kineros2.shp - outlet of a watershed to be modeled with KINEROS

Swat1.shp - outlet of a watershed to be modeled with SWAT

Swat2.shp - outlet of a watershed to be modeled with SWAT

Swat3.shp - outlet of a watershed to be modeled with SWAT

Vegas_soil.shp - STATSGO soils

Click on the "+" button again, and add the following grids to the view (*make sure you change the "Data Source Type" to "Grid data source"*):

Vegas_accum - flow accumulation map

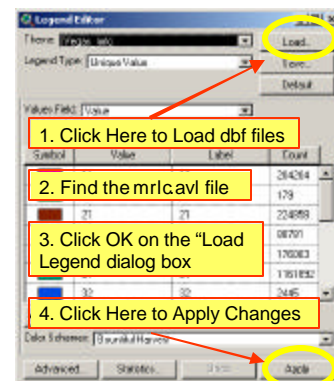
Vegas_dem - digital elevation model

Vegas_dir - flow direction map

Vegas_mrlc - MRLC land cover classification

To make the MRLC data look a little better, double-click on its legend. You will get a pop-up window like →

Click on the "Load.." button and navigate to select the **"mrlc.avl"** file that is located in your **"agwa\datafiles"** subdirectory. This will load in a legend with pre-defined colors and names that makes looking at the land cover data a little easier. Keep the default "Value" field in the pop-up and be sure to click the **"Apply"** button to set the changes.



Close the Las Vegas View and open up the "San Pedro" View. Repeat the above steps to add the following San Pedro GIS data:

Fairbank.shp - NWS Fairbank rain gauge

Nws_gages.shp - Multiple rain gauges throughout the basin

Uspb.shp - Outlet of the upper San Pedro subwatershed for SWAT

Sierra.shp - Putlet of the Sierra Vista subwatershed for KINEROS

Sp_soil.shp - STATSGO soils

Nalc_1973 - NALC 1973 land cover classification (60m)

Nalc_1997 - Landsat TM data classified into NALC cover categories (60m)

Sp_accum - Flow accumulation grid

Sp_dem - Digital elevation model

Sp_dir - Flow direction grid

You can make the NALC data look better by following the same approach for importing the NALC legend as you did in Las Vegas. The NALC data also has a legend, which is called “**nalc.avl**” under the “agwa” subdirectory.

Housekeeping hint: AGWA created a folder named “av_cwd” below the project directory. This folder is set as the working directory in ArcView so maps and tables created by AGWA will be placed there.

You will also need to add rainfall data to the project (otherwise you will be prompted to do so when the data is needed). To do so, close the San Pedro View and click on the “Tables” icon in the project:

Navigate through the agwa\datafiles subdirectory to add in the following .dbf files:

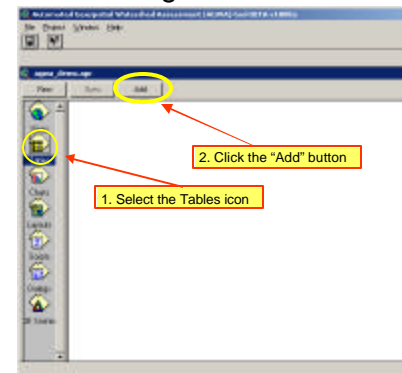
dsgnstrm.dbf – return period rainfall for KINEROS

Soil_lut.dbf – master look-up table for soil parameters

Sp60_73.dbf – San Pedro rainfall from 1960-1973 for all the NWS gauges in the basin

Vegas49_87.dbf – Vegas rainfall data from 1949-1987 for the airport rain gauge

Wgnfiles.dbf - database table of weather generator stations for SWAT



After loading these files into the project, you can close the ArcView Tables to clean up the display. AGWA will be able to find them.

At this point we have all the data necessary to start modeling:
topography, soils, land cover, and rainfall.

Part I: Modeling Runoff at the Basin Scale Using SWAT

At this point, it would be a good idea to **save your work**. ArcView is a little temperamental, so saving often is highly recommended.

Step 1: Subdividing the watershed

1. Open up the “San Pedro” view again. Take a look at the data you have available to you to become familiarized with the area. This is accomplished by checking the open boxes next to the legends. You can change the color ramps and display schemes of the GIS layers by double-clicking on them and manually adjusting the legend.
2. Make sure the “uspb.shp” layer is turned on and is located at the top of the list of available GIS layers. The uppermost themes are displayed last, and we would like to be able to see the location of the point. We will use it to mark the outlet of the watershed for modeling purposes.

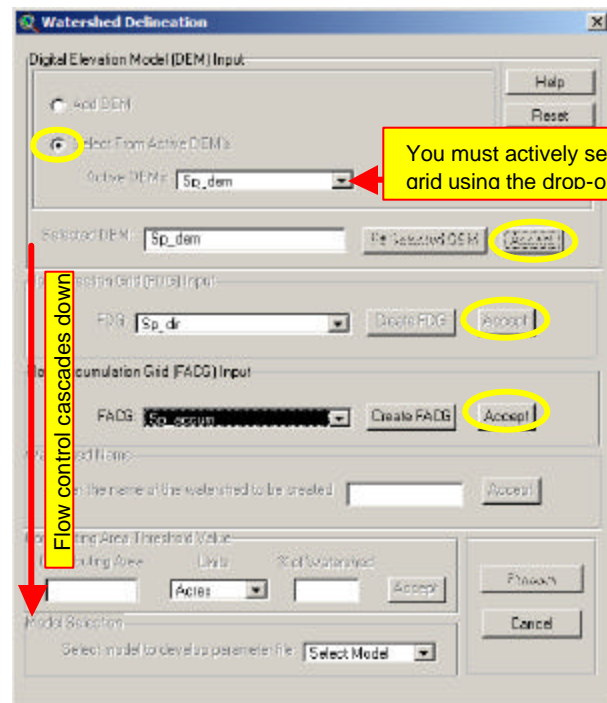
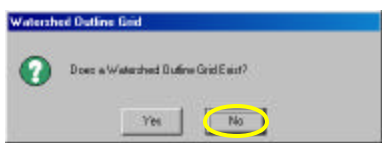
Start the AGWA tool by clicking on the “AGWA Tools” menu items and then on “delineate watershed”. You will be faced with a dialog box with lots of choices...

Fill in the dialog so that it looks like this picture →

If you have previously loaded the GIS data into the view, you should have the appropriate DEM, flow direction and flow accumulation maps available.

Once complete, click the last “Accept” button and you will be prompted to generate a watershed outline.

Since this is the 1st time through, a watershed outline does not exist.



A Brief Note on AGWA Speed

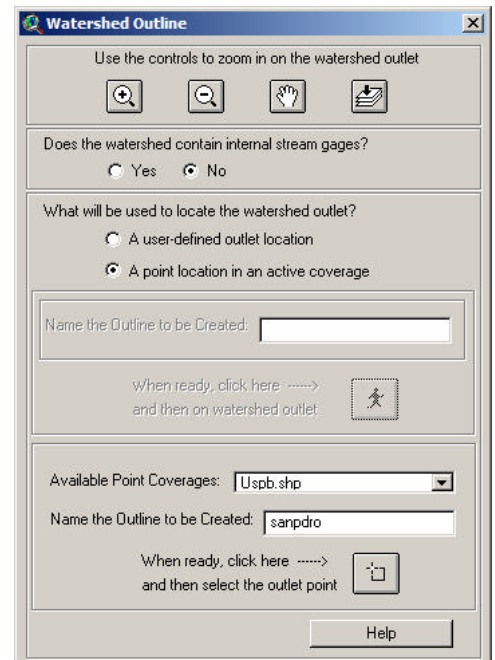
The 1st time through this step, AGWA creates a stream network (stream2500) to act as a visual guide for watershed delineation. This can be time-consuming, but it only happens once per DEM.

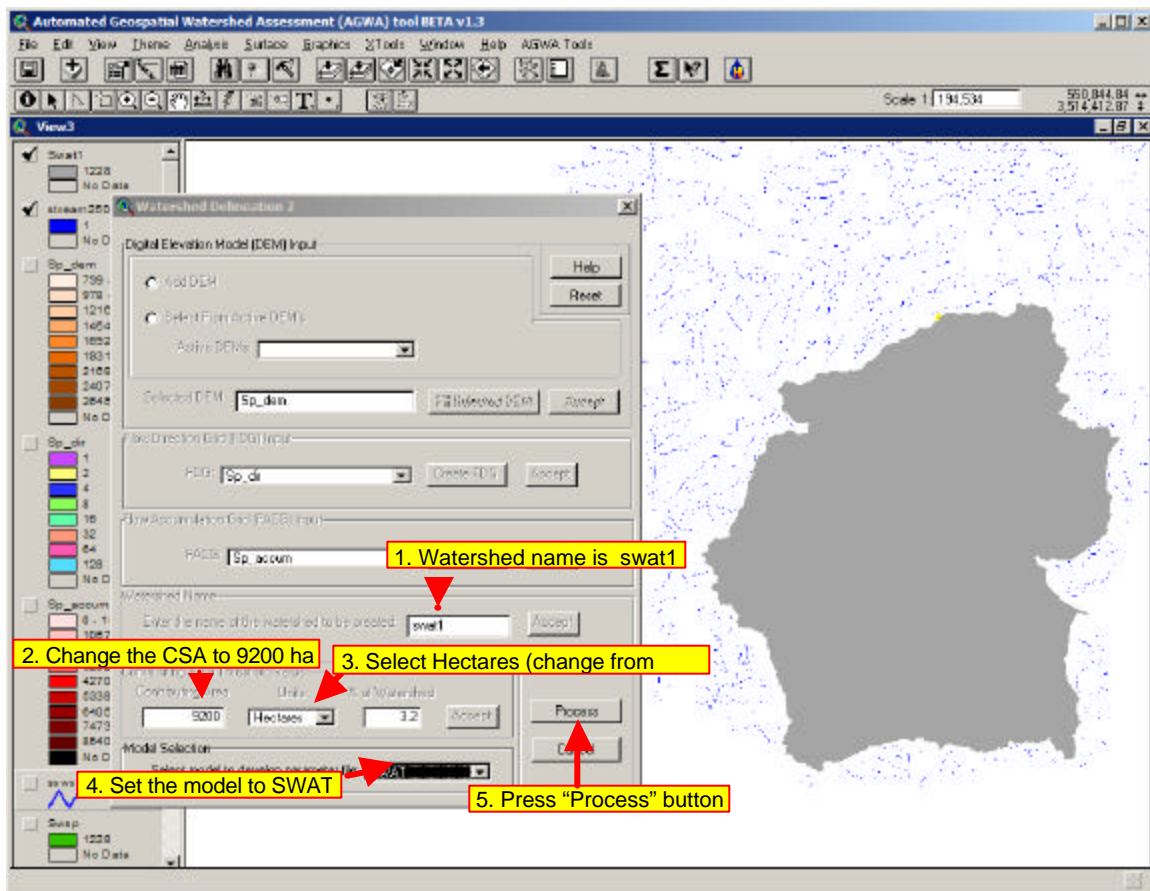
- Fill in the next dialog box so that it resembles the picture here →

Once you click on the box in the lower right corner AGWA will expect you to **draw a box using the mouse around the location of the uspb.shp point**. Use the left mouse button to drag a box around the point's location. You might have to move the uspb.shp file to the top of the list of legends and make it visible.

AGWA will proceed to generate a grid that delineates the outline of the watershed contributing runoff to the uppermost San Pedro River Basin. AGWA will ask if the watershed looks OK. Since the point is pre-made, it probably is...

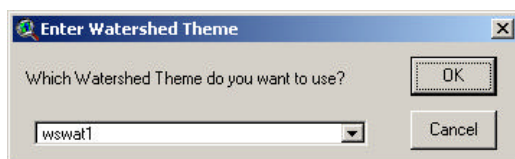
- At this point, the outline of the watershed should have been successfully created, and you will be back at the “Watershed Delineation” dialog box. *Here you will be creating a watershed named "swat1".* AGWA subdivides the watershed into hydrologic elements based on the channel support area (CSA) approach, wherein the channels are defined by the user as a function of the Contributing Area: smaller numbers entered here will result in a more complex watershed. AGWA defines the default CSA as 2.5% of the watershed. **Change the CSA to 9200 hectares**, the model selection to **SWAT** and hit the Process button.



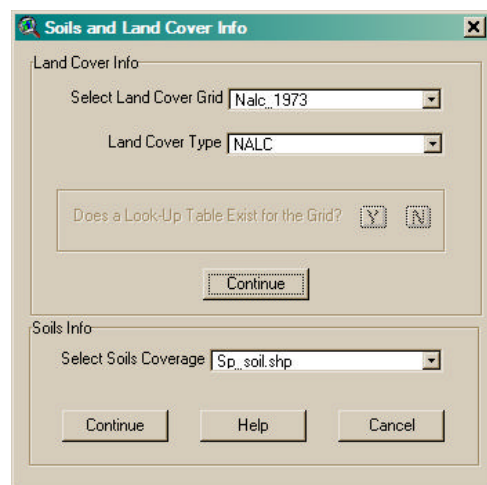


Step 2: Characterize the watershed elements for SWAT model runs

1. Each of the modeling elements needs to be characterized according to its unique properties of land cover and soils. These properties are used by AGWA to provide input parameters to either SWAT or KINEROS. To start this process, select on **"AGWA Tools... Run Landcover and Soils Parameterization"**.



Note that AGWA has created a subwatershed with the swat1 suffix and placed a "w" in front of the subdivided watershed map (wswat1). A channel map is also in the view named "sswat1". Fill in the landcover & soils dialog box as shown here → then press the Continue button. AGWA will run through some machinations to prep the wswat1 watershed for running SWAT using 1973 land cover and STATSGO soils.



- At this point the watershed has been subdivided into model elements and these elements have been characterized according to their land cover and soil properties. AGWA has added a few items to the watershed's data table that will be used to provide input to the SWAT model. You can see these changes by selecting on the legend for wswat1 and then clicking on the *Table* icon that looks like:



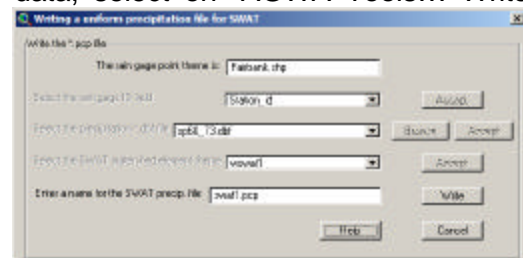
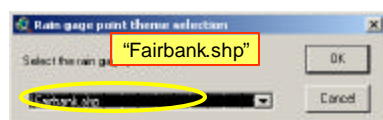
Step 3: Prepare rainfall files

- AGWA provides a means for preparing rainfall files in SWAT- or KINEROS-ready format. The key is that the user has previously prepared a dbf file containing daily estimates of rainfall for the rain gauges within the study area. Rainfall data for gauges within the San Pedro are provided to you in the “*sp60_73.dbf*”.
- When AGWA is used expressly as a hydrologic modeling tool it is critical that the rainfall data be spatially distributed across the watershed. A large body of literature exists regarding the crucial nature of spatially distributed rainfall data. Given a number of rain gauges scattered throughout the study area (see the nws_gages data layer), AGWA will generate a Thiessen rainfall map and distribute observed rainfall on the various watershed elements using an area-weighting scheme. Feel free to use the nws_gages file in concert with the sp60_73.dbf file to generate rainfall data, but we are *NOT* using this option right now.

Note on rainfall input: The process of creating area-weighted rainfall files is very time-consuming (it can take several hours to characterize a complex watershed for many years of rainfall) and we are avoiding it during this exercise. Instead, we will use a single rain gauge to generate a uniform rainfall file across all the model elements. This is obviously a huge deviation from using observed data, but there is a sound reason for doing so in change detection work. We are interested in the impacts of land cover change on hydrologic response, but the spatial variability in rainfall can have confounding effects on the analysis, swamping out the isolated changes within the subwatershed elements. Using homogeneous rainfall serves to isolate the effects of land cover change independent of the rainfall.

**** Thought Provoking Topic **** You can try using 2 different sources of rainfall data for SWAT: uniform and distributed rainfall. In this example you will use a single gauge, but you could also try running SWAT with the “nws_gages” shapefile and use all available gauges for the same time period. In this way you can investigate the impacts of rainfall input on hydrologic modeling.

- To generate the homogeneous rainfall data, select on “AGWA Tools... Write SWAT Precipitation file” and fill in the dialogs as:



Hit the “Write” button and save the .pcp file as “**swat1.pcp**” in the “rainfall” folder in your project.

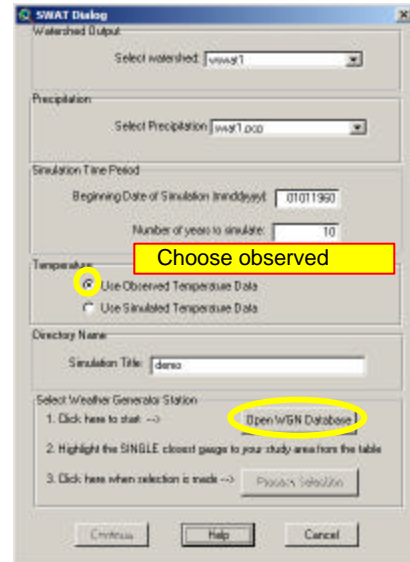
Step 4: Write output and run SWAT

1. At this point all the pieces are in place to run SWAT. The last step is to click on “AGWA Tools... Write Output and Run SWAT”. You will be prompted with the following screen:

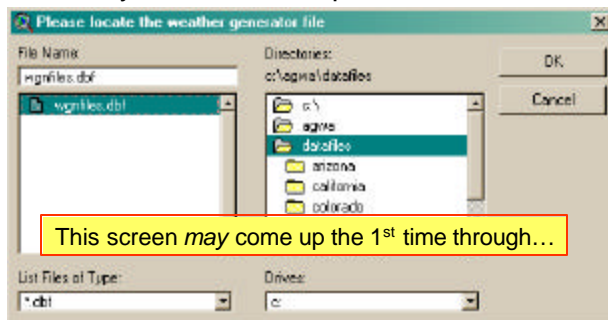
Once you select the watershed AGWA will provide you with the available precipitation files that you have created for the watershed. If you have generated multiple rainfall events, AGWA keeps track of them for you.

There are 14 years of data in the rainfall record you created earlier. You can change the start and end dates so long as they fall between January 1, 1960 and Dec 31, 1973 (AGWA keeps track of this also).

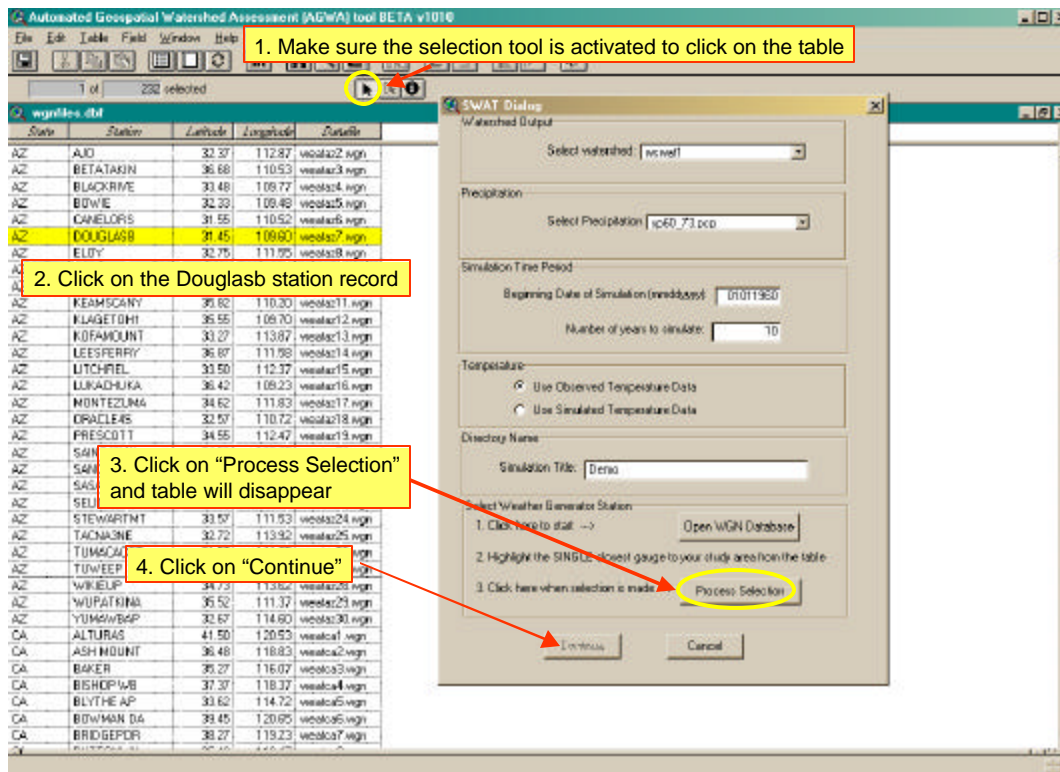
For simplicity, keep the default start date as January 1, 1960 and **simulate 10 years of runoff**.



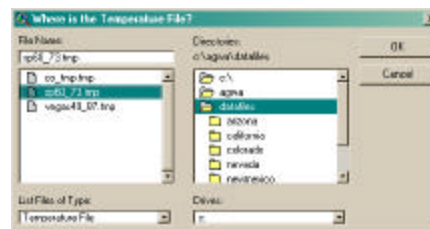
2. When you click the “Open WGN Database” you may be prompted to select a weather generator file. If the master database file containing weather record locations (wgnfiles.dbf) has not been added to the project, you must do so here. It can be found in the “datafiles” folder under “agwa”.



Once the wgnfiles.dbf file is added to the project, you will need to select on the weather station closest to your study area. You will be shown a list of the available stations. **Note:** AGWA will show the name, latitude and longitude of the available stations, but it is the responsibility of the user to choose an appropriate station. In the San Pedro, choose the **DOUGLASB** station. Fill in the dialog so that it looks like the picture shown here.

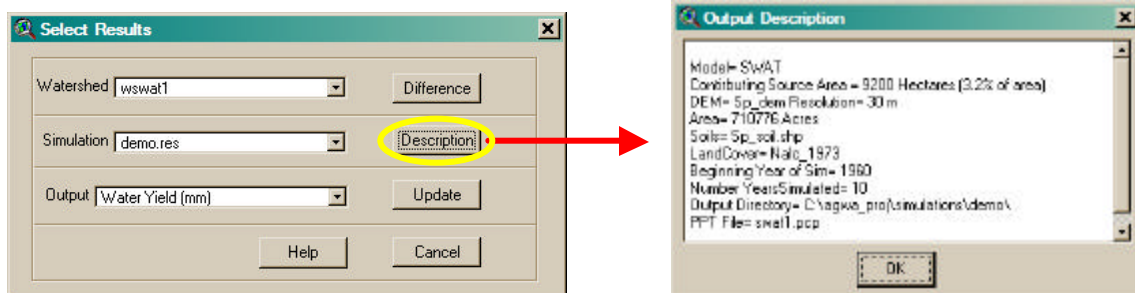


3. The first time you run SWAT, you may be prompted for the location of the SWAT executable. It can be found in "agwa\models" and is called "swat2000.exe". Likewise, you can find the temperature file in the "agwa\datafiles" directory as "sp60_73.tmp":



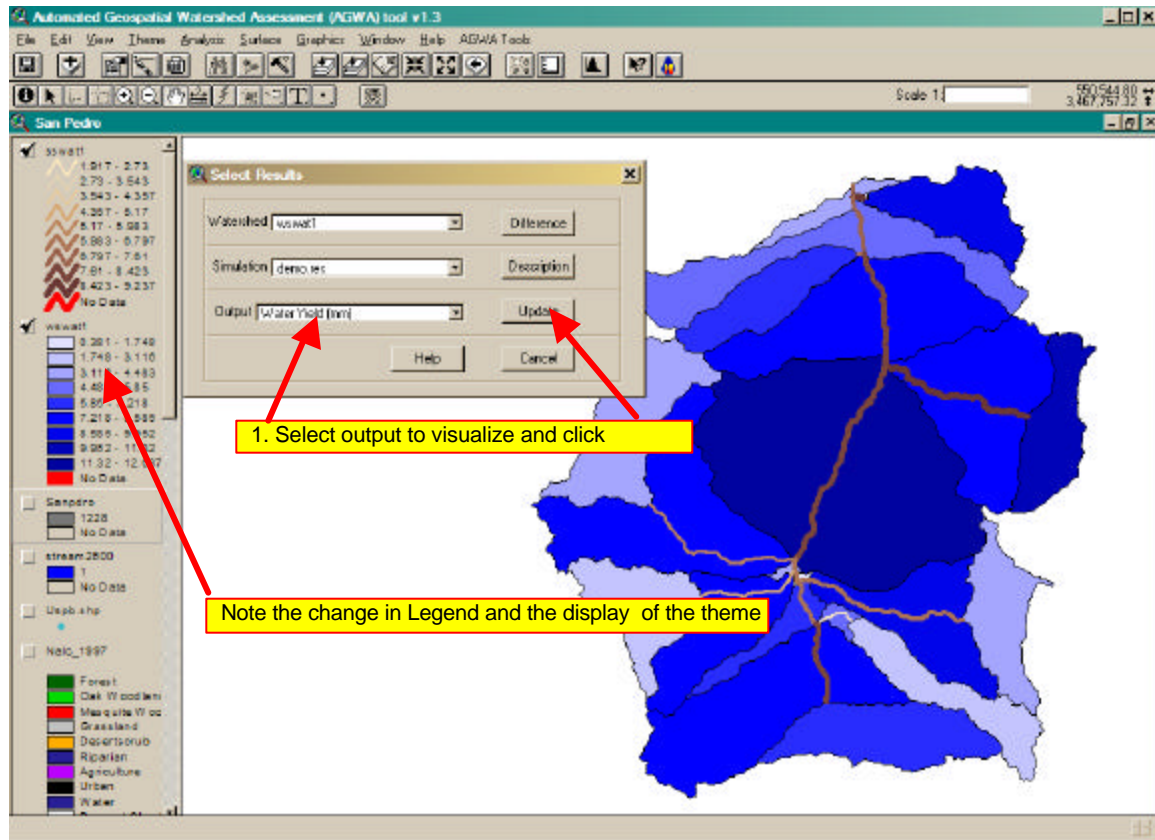
Step 5: View the results

1. After SWAT runs to completion, AGWA scarfs up the output data created by SWAT and attaches the results back to the GIS data in the view (in this case, wswat1). You can display the spatially distributed runoff, infiltration, and other water balance results by clicking on "AGWA Tools... View SWAT Results". You will be presented with a dialog as:



Click on the “Description” button to review the choices you made to get to this point. This box provides a summary of the data used to provide input to SWAT. In this case, the watershed size was 710776 acres with a CSA of 9200 hectares. 1973 NALC and STATSGO soils were used to parameterize the watershed for a 10 year model run starting in 1960.

2. Experiment with the visualization tool by choosing different results to display. The results for water yield should look like:



Step 6: Repeat for 1997 land cover

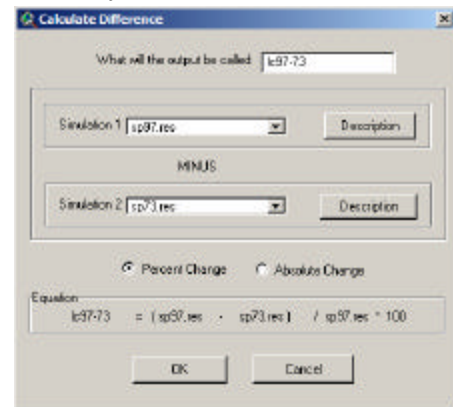
1. You do not have to re-configure the watershed. Start the process at Step 2 from above, choosing the Nalc_1997 land cover data this time.
2. You do not have to re-produce rainfall data since the geometric watershed configuration is exactly the same.
3. Go through the same approach as above to generate 5 years of runoff data for the basin given 1997 land cover, STATSGO soils, and homogeneous rainfall. In this case, write the results to “simulations” folder and use the prefix “sp97”.
4. Visualize your results. Note that the patterns are similar in display, but the regional magnitudes are different. To inspect these changes, continue on....

Step 7: Compare the 1997 results with the 1973 results

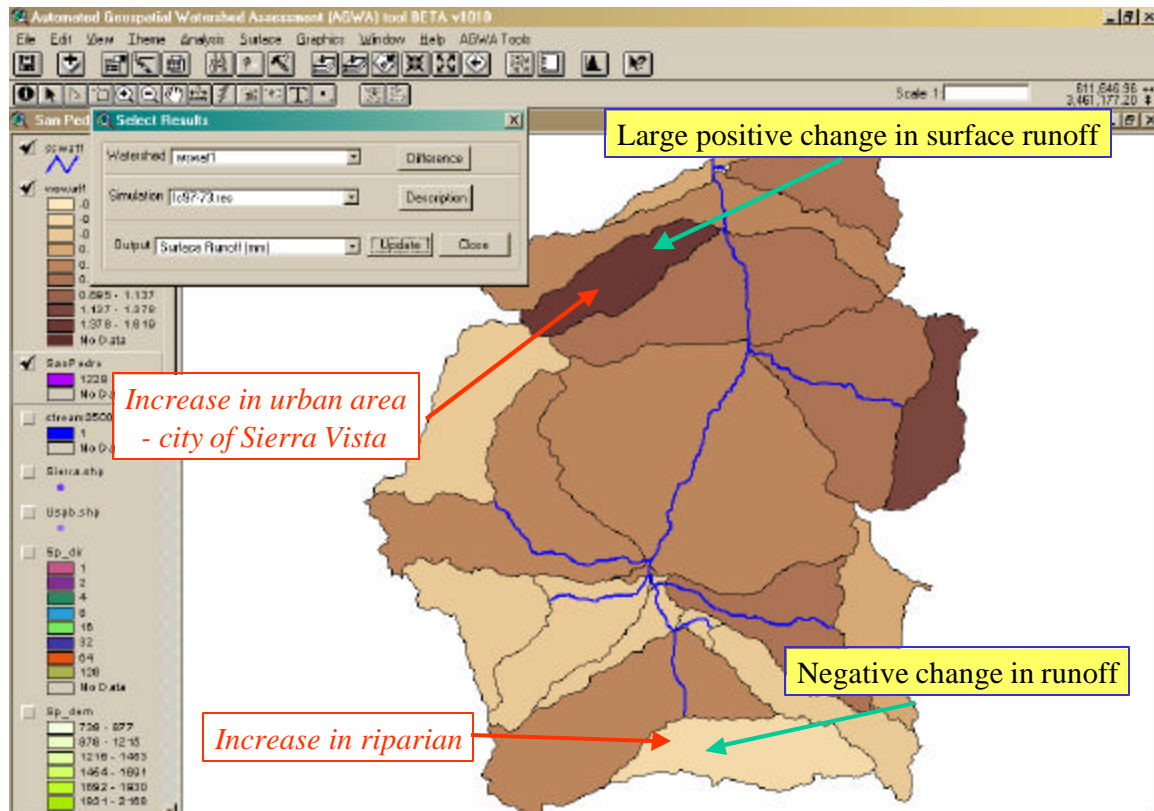
1. Click on "AGWA Tools... View SWAT Results". Once you have selected "wswat1", click on the "**Difference**" button, and you will be prompted with this dialog:

Here we are creating a new data layer with the differences in runoff between the 1997 and 1973 land cover classes. This approach is a simple subtraction, so negative values will occur where runoff is predicted to decrease due to beneficial changes in the land cover.

Name the output "lc97-73" to indicate the direction of subtraction. Here (+) indicates an increase in runoff



Results of the simulated change in water yield resulting from land cover changes are shown below:

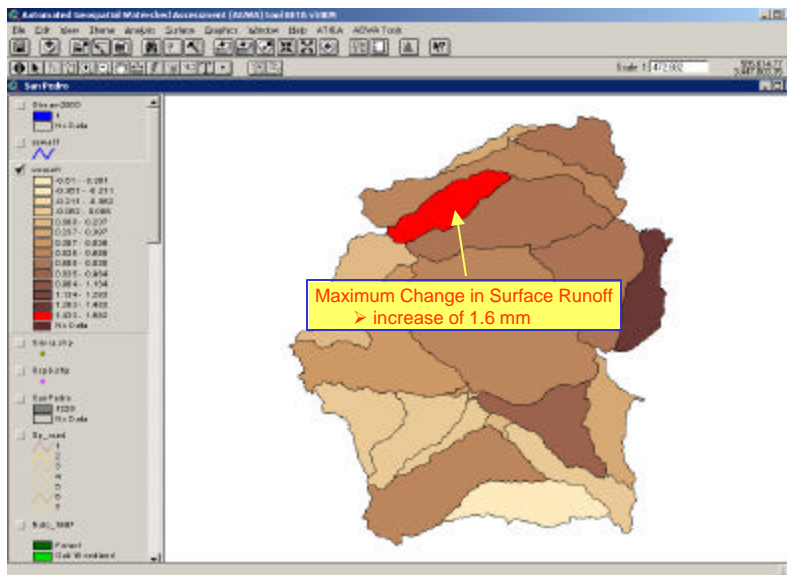


Part II: Modeling Runoff at the Small Watershed Scale Using KINEROS

In the previous two sections we identified regions that have undergone significant changes both in terms of their landscape characteristics and their hydrology. These basin scale assessments are quite useful for detecting large patterns of change, and we will use the results to zoom in on a subwatershed to investigate the micro-scale changes and how they may affect runoff from simulated rainfall events.

SWAT is a continuous simulation model, and we simulated runoff for 10 years on a daily basis. KINEROS is termed an event model, and we will use design storms to simulate the runoff and sediment yield resulting from a single storm, in this case the estimated 10-year, 60-minute return period rainfall.

A quick review of the spatial distribution of changes in surface runoff predicted by SWAT shows that the largest increase occurred in a small watershed draining an area near Sierra Vista that underwent significant urban growth from 1973 – 1997.



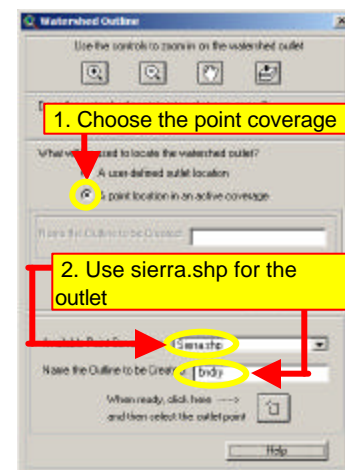
The area near Sierra Vista is highlighted in red.

We are going to zoom in temporally & spatially to investigate large-scale changes within the watershed.

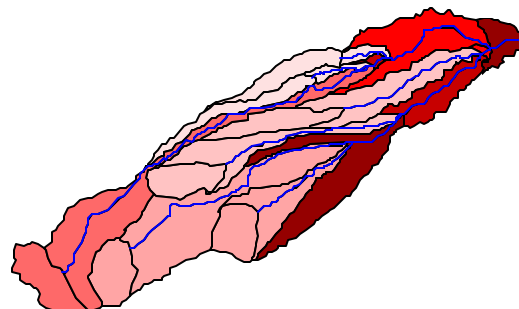
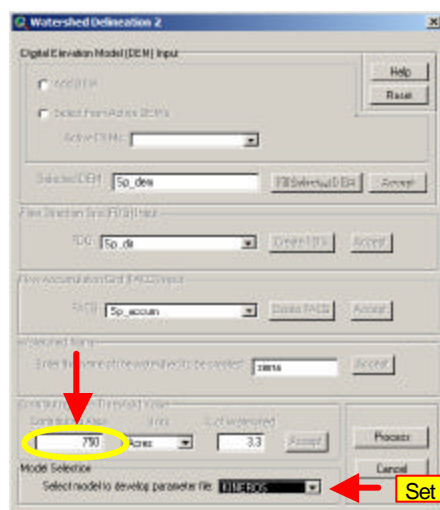
Step 1: Subdividing the watershed

1. As we did for SWAT, the first step is to generate an outline for the watershed in question. You might want to clean up the view a bit by turning off theme layers that are not useful and making sure that the “**Sierra.shp**” file is at the top of the stack of legends. This point will serve as the outlet of the next exercise.
2. Start the AGWA tool by clicking on the “AGWA Tools” menu items and then on “delineate watershed”. Use the same DEM, flow direction, and flow accumulation maps as before. **Note: since we are zooming into a new area, you should answer NO to the question “Does a watershed outline exist?”.**

3. Fill in the dialog box so that it resembles →
4. Drag a box around the point representing the outlet of the watershed as you did before in the SWAT exercise. Use the left mouse button to define the box.
5. A watershed outline will be created that closely matches the shape and size of the area identified as undergoing the most change in the SWAT exercise. Now we will subdivide the watershed for input to KINEROS...



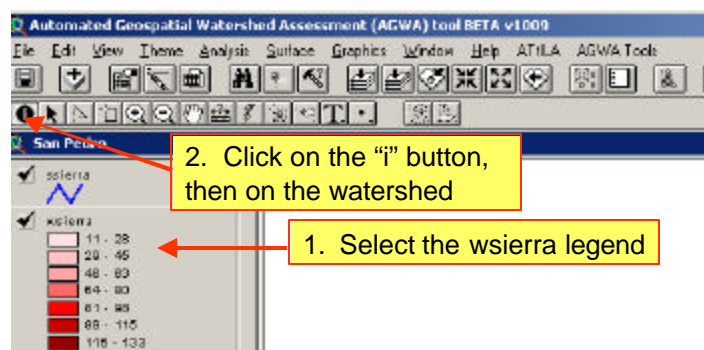
6. For the KINEROS model, set the CSA to 750 acres, and be sure to change the model type to KINEROS, not SWAT. These models require significantly different watershed subdivisions and will not work on each others' watershed geometry. The watershed should look something like:



Set model to KINEROS

Step 2: Characterize the watershed elements for KINEROS model runs

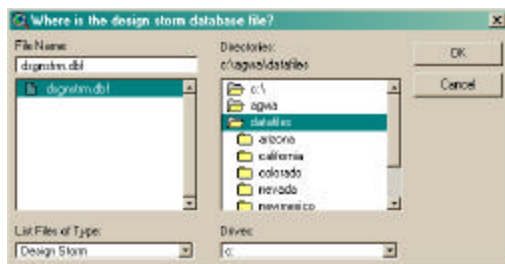
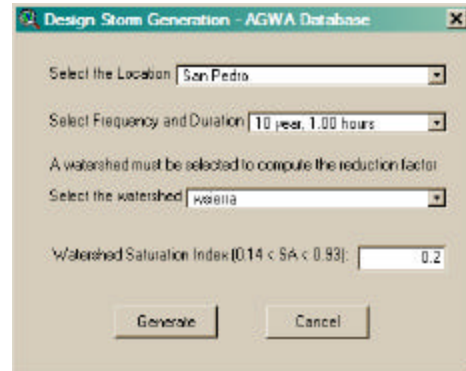
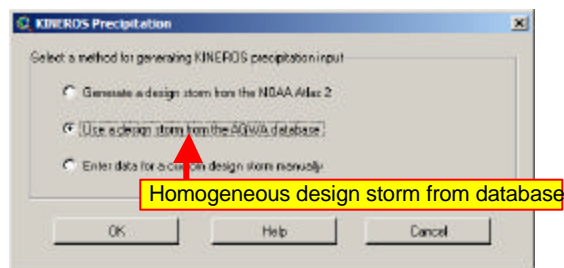
1. As in SWAT, you must intersect the watershed elements with the land cover and soils data to generate parameters for the hydrologic modeling exercise. Click on "AGWA Tools... Run landcover and soils Parameterization". Choose the **NALC_1973** and **sp_soils** layers for the intersection.
2. You can check the way in which the watershed gets parameterized for KINEROS by following the steps given here →. Note that there are a lot more parameters readied for input to KINEROS than SWAT at this point.



Step 3: Prepare Rainfall Files

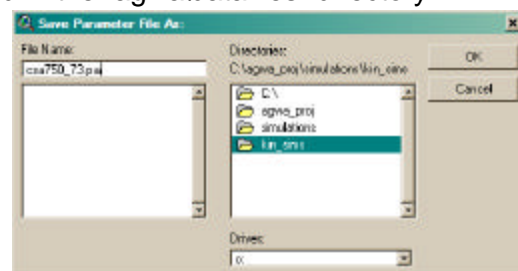
KINEROS is designed to be run on rainfall events. AGWA has a number of return period events for SE Arizona stored in its database. We are going to use one of the pre-defined storms, but AGWA allows you to create rainfall data for KINEROS in one of 3 ways:

1. Homogeneous design storm from the database (our technique).
 2. Homogenous rainfall input by the user.
 3. Heterogeneous rainfall input by the user – this is used in the case where there are a number of rain gauges within the watershed. KINEROS handles the rainfall interpolation, so each gauge must have a defined hyetograph.
1. Click on “AGWA Tools... Write KINEROS Precipitation File”. Fill in the dialog box so that it resembles the picture on the right. Increasing the watershed saturation index will increase the simulated runoff since losses to infiltration will be lessened. Likewise, increasing the return period will increase the runoff since longer return period storms have greater rainfall depths. We'll pick a middle ground for this exercise (10 year, 60 minute with 0.2 saturation).



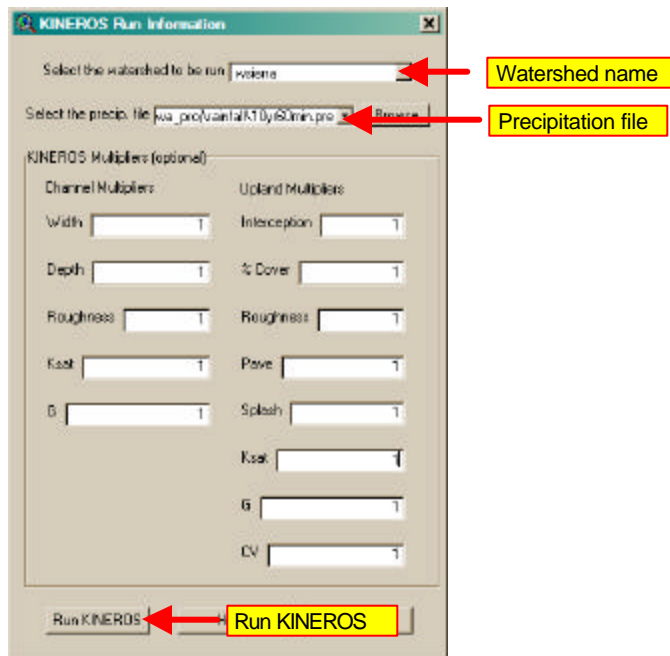
If the “dsgnstrm.dbf” file has not been added to the project, AGWA will ask you for it. It can be found in the “agwa\datafiles” directory.

2. Save the precipitation file in the “rainfall” folder as “10yr60min.pre”.



Step 4: Write output and run KINEROS

1. At this point you have all the data you need to run KINEROS on the Sierra watershed. Click on “AGWA Tools... Write Output File and Run KINEROS”.
2. The first time through, AGWA will ask you for the location of the KINEROS executable. It is in the “agwa\models” directory and is named “**kineros2.exe**”. The Kin95.exe can be used outside of AGWA and provides a GUI interface to running KINEROS and some additional visualization tools. AGWA uses a stripped down version of KINEROS for simplicity. Choose the precipitation file you just created when prompted to do so, and KINEROS should run to completion in a DOS window.

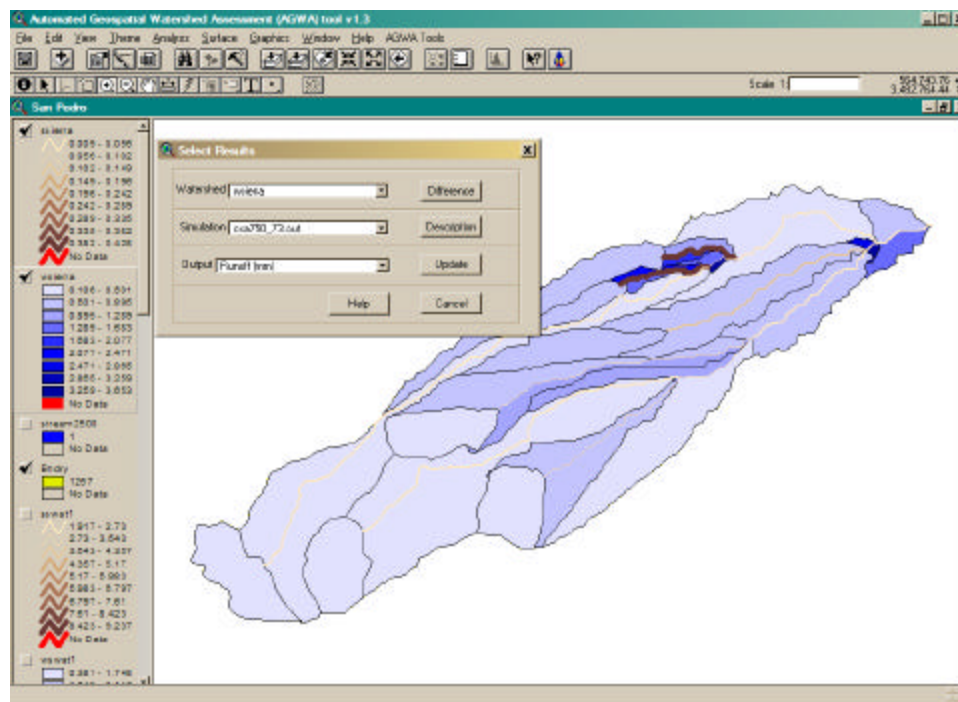


AGWA allows for the use of parameter multipliers in the development of input parameter files for KINEROS. The multipliers can be very useful for calibration / validation studies but are not necessary for our purposes. We will use the default multiplier values of "1", thereby leaving the parameter estimation alone.

Save the parameter file in the "simulations" directory as "csa750_73" (CSA = 750 acres, land cover = NALC 1973).

Step 5: View the results

1. Viewing the KINEROS results is identical to looking at SWAT results. Click on "AGWA Tools... View KINEROS Results" and choose the sierra watershed with the **csa750_73.out** file generated by the KINEROS run.

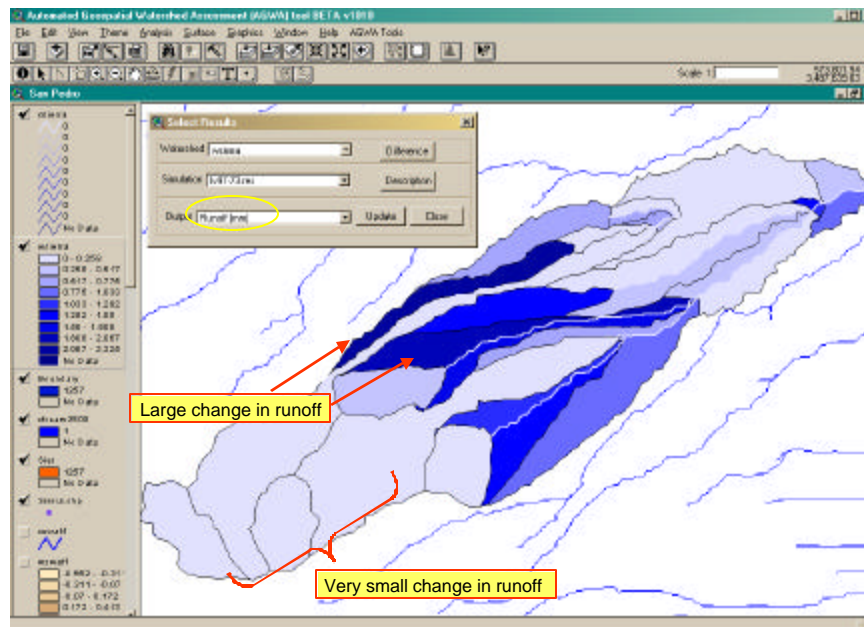


Step 6: Repeat for 1997 land cover

1. Re-run the land cover and soils parameterization, this time for the 1997 NALC data.
2. You do not need to re-generate a rainfall file.
3. Generate a new .par file ("AGWA Tools.. Write Output File and Run KINEROS") Name the file **csa750_97.par** and place it in the "simulations" directory.
4. Visualize your results. Note that the patterns are similar in display, but the regional magnitudes are different. To inspect these changes, continue on....

Step 7: Compare the 1997 results with the 1973 results

1. Click on "AGWA Tools... View KINEROS Results" and follow along the way you did with the SWAT results to visualize the spatial patterns of hydrologic change. Your results for runoff should look something like this:



The question should arise: what is driving this change in runoff? You can inspect the changes in the underlying land cover and make some correlations.

The driving forces behind the change are primarily decreases in cover, surface roughness and infiltration.

Results and Interpretations

In this exercise we used two hydrologic models to look at small- and large-scale changes within a basin. The SWAT model revealed some basin-wide trends and isolated portions of the basin that have undergone significant annual changes in their hydrology due to shifts in land cover. KINEROS was used to “zoom in” both temporally and spatially on the portion of the watershed identified by SWAT as having undergone the most negative change due to increased urbanization.

Some statistics to which you can compare your results for verification:

For the SWAT Runs

- a. 3.36 → 3.91 mm. Change in total annual surface runoff at the outlet of the watershed from 1973 and 1997 land cover.
- b. 9.57 → 9.13 mm. Change in total groundwater recharge (basin-wide).
- c. 1.58 & -0.51 mm. Maximum and minimum change in surface runoff depth for a single subwatershed element from 1973 to 1997.
- d. 0.90 & -0.5 mm. Maximum and minimum change in transmission loss for a single subwatershed element from 1973 to 1997.
- e. 0.68 & -0.12 mm. Maximum and minimum change in water yield for a single subwatershed element from 1973 to 1997.

For the KINEROS Runs

- f. 650 → 17010 m³. Change in total runoff simulated at the watershed outlet using 1973 and 1997 land cover.
- g. 6.2 → 8.8 kg/ha. Change in total sediment yield at the outlet.
- h. 2.3 & 0.0 mm. Maximum and minimum increase in runoff on a single watershed element between 1973 and 1997.
- i. -1.85 & 0.034 mm. Maximum and minimum changes in infiltration on a single watershed element.
- j. 29,944 & 0.0 kg. Maximum and minimum changes in sediment discharge on a single watershed element.

Some question to think about that may be answered using this multi-faceted approach:

- a. What regions of the basin have undergone significant change in their landscape characteristics?
- b. How have these changes in the spatial variability impacted runoff, water quality, and the water balance?

- c. Given spatially distributed changes in the water balance, what stresses (or benefits) are placed on the plant community or habitat? Can we identify regions of susceptibility or especially sensitive areas?
- d. How may these tools be used in a forecasting model or land cover simulation scenario to identify “at-risk” or sensitive areas?
- e. How do the spatial patterns of change affect runoff response? How can we optimize landscape and hydrologic assessment as a function of temporal and spatial scaling?

Some Additional Exercises to Try on the San Pedro

- 1. Change the CSA to see how altering the geometric complexity impacts the simulation of hydrology and landscape statistics.
- 2. Use the MRLC from the early 1990s to simulate runoff and compare it with the commensurate 1992 NALC data to see how different land cover classifications affect the results.
- 3. Use the “nws_gages” coverage to generate spatially-distributed rainfall for input to SWAT. This approach will create a Thiessen map across the watershed and you will notice a distinct S-N gradient in rainfall depths that affect the generation of runoff and also impact the change statistics.
- 4. Generate a variety of rainfall events for KINEROS and investigate the relative impacts of land cover change on small vs. large return period storms. You should see a drop in percent change with increasing rainfall. Why?